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Simulation of Rough Surface Scattering in Three-Dimensions

Quarterly Report

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by

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SUMMARY

In the last quarterly report the standard iterative approach was used to solve the integral equation for the surface current density on a perfectly conducting surface. The number of iterations necessary was established to be only one to obtain a good agreement (within 1 dB) between the iterative method and the standard moment method when the incidence angle was smaller than 60 degrees and the rms slope smaller than 0.4. While three-dimensional surface scattering problem can be solved with this method, it was found to be time consuming. For this reason further study has been made to look for a more effective method by finding an optimum basis function to represent the unknown field. During the past quarter a spectral representation was used to represent the scattered field and the tangential boundary condition was used to determine the scattered field directly. Initial test was carried out for a two-dimensional surface scattering problem. It was found that an hour calculation on VAX 8700 using the standard moment method could be reduced to 3 minutes with the present technique.

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1. INTRODUCTION

It is well known that for a perfectly conducting surface only the tangential boundary condition is needed to determine the unknown scattered field. By using the spectral representation for the scattered field it is possible to convert this boundary condition into an integral equation. For a two-dimensional surface scattering problem it takes the form,

$$- e^{-j k x \sin \theta + j k z(x) \cos \theta} = \int_{-\infty}^{\infty} f(k_x) \exp[-j k_x x + j k_z z(x)] dk_x \quad (1)$$

where the left hand side is the incident electric field, θ is the incident angle; k is the wave number and $z(x)$ represents a rough surface. The right hand side of the equation is the spectral representation of the unknown scattered field and $f(k_x)$ is the unknown amplitude to be determined by solving the integral equation. Using the moment concept we can multiply both sides of the equation by $e^{-j k x \sin \theta + j k z(x) \cos \theta}$ and integrate x over the illuminated area. The idea here is to use a large enough illuminated area so that after integration the right hand side becomes a narrow function of k_x . This expectation is based on the Fourier theorem which indicates that a wide spatial function is narrow in frequency space and vice versa. Thus, only a few basis points are needed to represent $f(k_x)$ in k -space. As a result while solution in a very large x -space (i.e. large illuminated area) by the moment method requires an excessively large memory space and computational time, in k -space it requires only a small number of points and becomes very economical! Based on this concept calculations were performed for two-dimensional surface scattering problems to establish the minimum

size of the illuminated area and the number of points per wavelength in the next section. This is followed by Section 3 where comparisons are made with the moment method calculations for different surface rms height parameters and surface correlation parameters.

2. CONDITIONS FOR THE PRESENT METHOD

As stated in the previous section the illuminated area must be large enough to reduce the computational size in k-space. Thus, the question arises as to what size is considered large enough. In Fig.1 backscattering computations are performed for a random surface characterized by a rms height, σ , and a Gaussian correlation function with correlation length, l , normalized to the wave number, k . Three different sizes of the illuminated area are considered: $D = 10, 15, 20$ wavelengths. It is seen that the cases with $D=15$ and 20 wavelengths are quite close together while the case with $D = 10$ wavelength is clearly different. Thus, we conclude that $D = 20$ wavelength is sufficient for this method. Next, we examine the required number of points per wavelength. This study is shown in Fig.2 where 8, 12, and 48 points per wavelength are considered. It is apparent from the figure that the difference between the use of 12 and 48 points is insignificant, but the use of 8 points per wavelength does give different results. Hence, we believe the required number of points is around 12.

3. COMPARISONS WITH THE MOMENT METHOD

To test the new method backscattering coefficients are computed for three different roughness conditions. Figure 3 and 4 show the effects of a change in the normalized correlation parameter from $kl = 4.2$ to 8.4 . In these figures moment method computations are denoted by MM while the calculations using the present method are indicated by FM. Results indicate that the current method works well in both cases. To examine a change in surface rms height parameter we show in Fig.5 a surface with a normalized rms height, $k\sigma = 1$ as opposed to 0.6 in Fig. 4. Here, there is an appreciable difference between the moment method

calculations and the new method denoted by FM especially at large angles of incidence. We believe this is due to the spectral representation used in (1) where it is seen that only waves propagating in the negative z-direction (i.e. upper propagating waves from the surface) are included. For a rough surface some waves are scattered forward and then rescattered backward by the surface. Thus, the representation of the scattered field in (1) is incomplete since it does not account for surface slope effects. We shall investigate this point further in our next report.

4. CONCLUSION

We are currently investigating a new approach to surface scattering simulation with the aim that it will be practical and efficient for the three-dimensional scattering problem. At this point in time only a partial success has been achieved for relatively smooth surfaces. However, the saving is significant. The standard moment method calculation requires one hour on VAX 8700 to compute 10 surface scattering samples using a surface size of 20 wavelengths and 12 points per wavelength while the current method requires only 3 minutes to do the same calculation. Hence, further study to extend the capability of the current method to deal with surfaces with larger rms heights is warranted.

FIGURE LEGENDS

Fig. 1 Determination of the size of the illuminated area , D

Fig. 2 Determination of the number of points per wavelength

Fig. 3 Comparison between the backscattering calculations using the standard moment method (MM) and those using the present method (FM) for $k\sigma = 0.6$ and $kl = 4.2$

Fig. 4 Comparison between the backscattering calculations using the standard moment method (MM) and those using the present method (FM) for $k\sigma = 0.6$ and $kl = 8.4$

Fig. 5 Comparison between the backscattering calculations using the standard moment method (MM) and those using the present method (FM) for $k\sigma = 1.0$ and $kl = 8.4$

HH Polarization

Samples average = 10

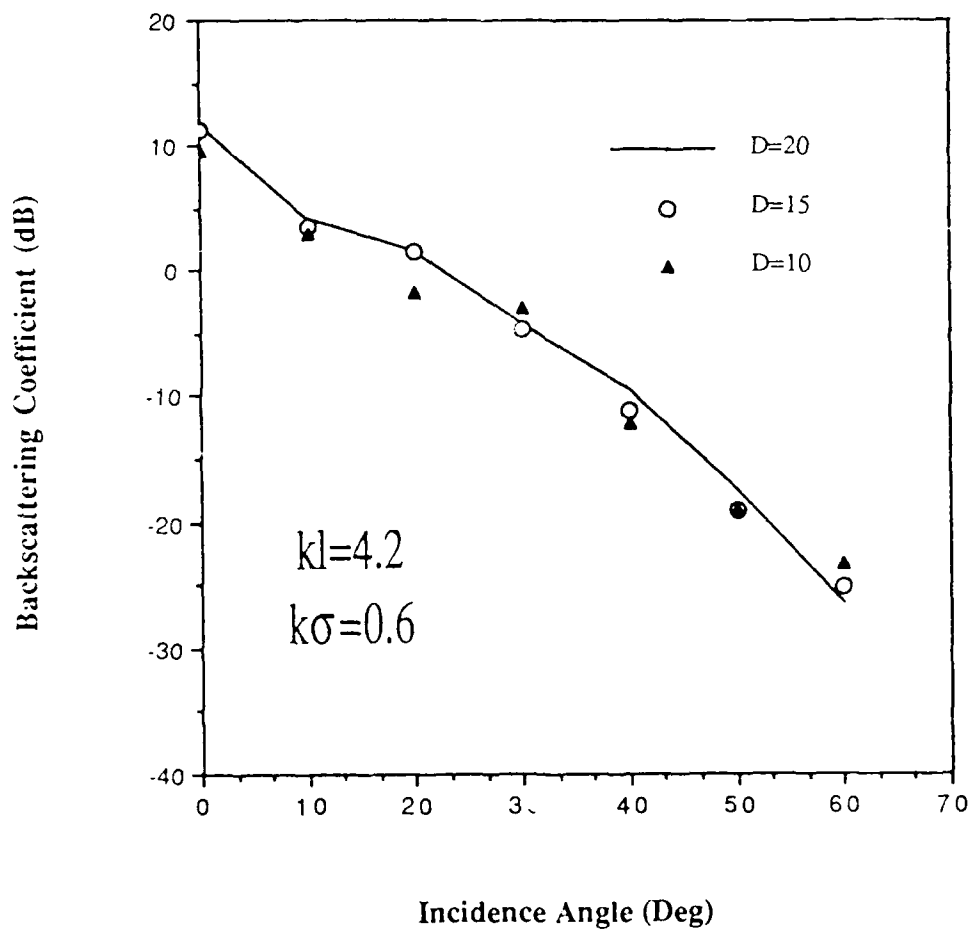
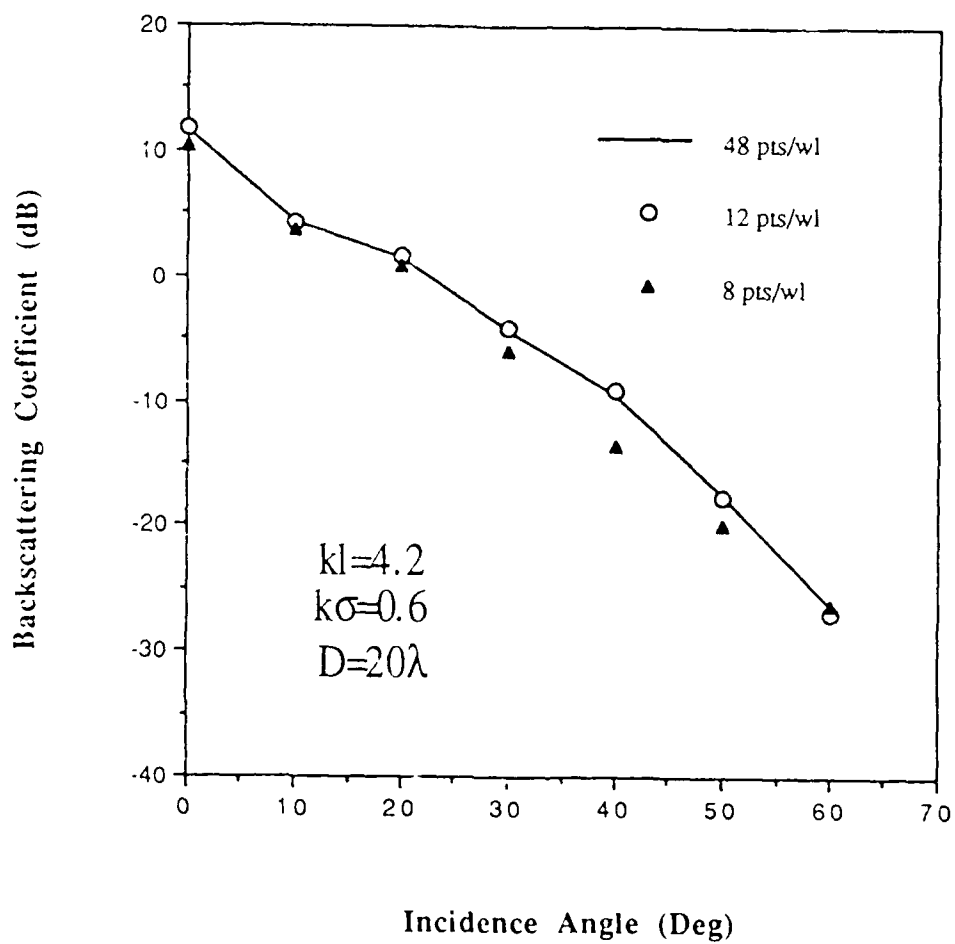


FIG. 1

HH Polarization

Samples average =10



HH Polarization

Samples average = 10

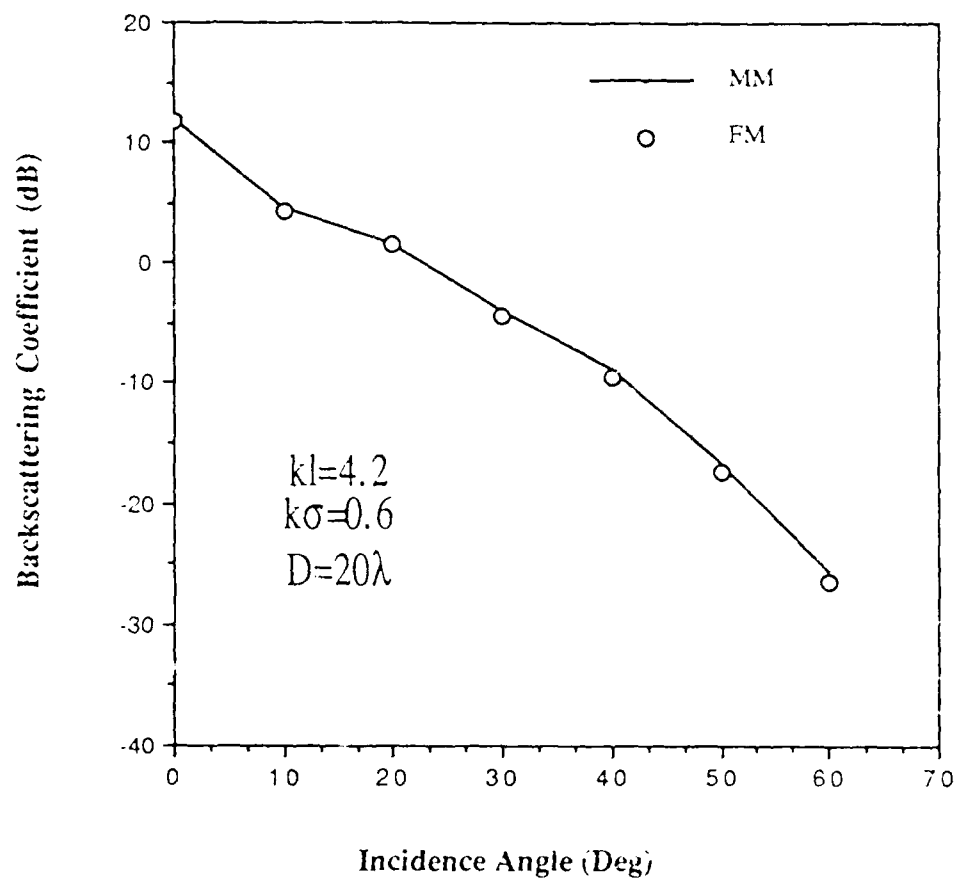


FIG 3

HH Polarization

Smamples average = 10

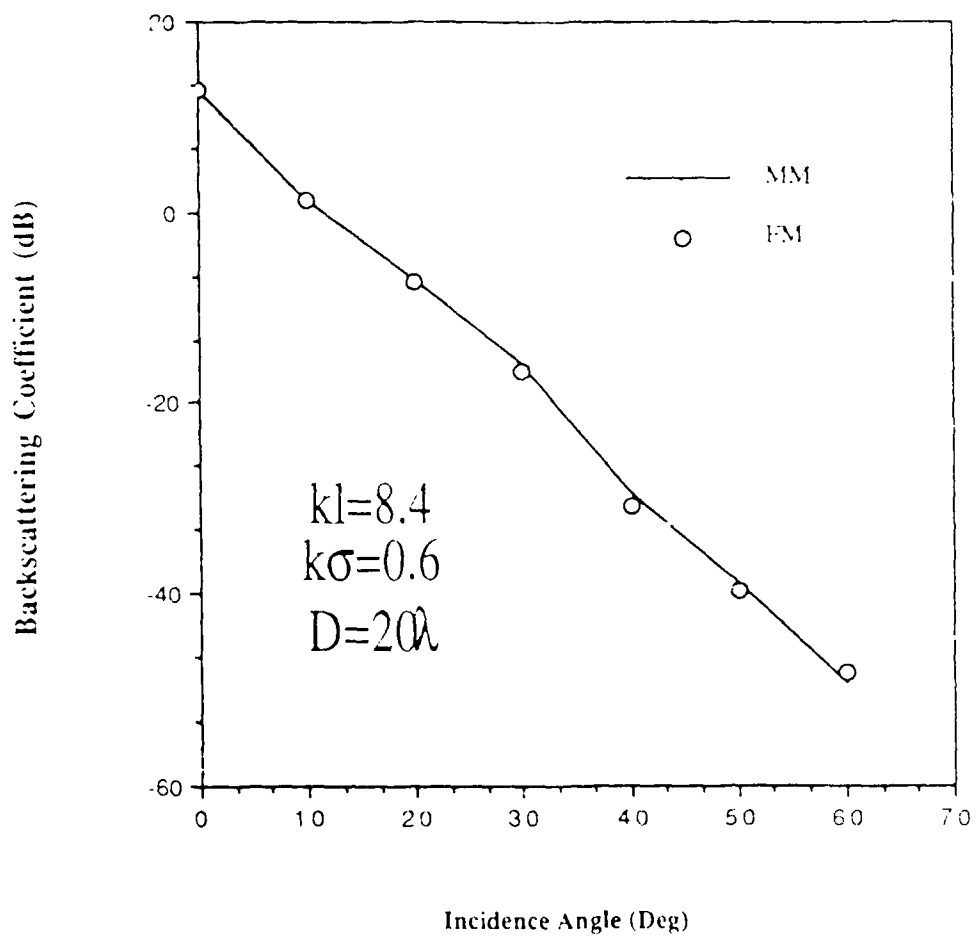


FIG. 2

